Response Spectrum Analysis of Multi Storied Building on Sloping Ground with Ground, Middle and Top Soft Storey

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ABSTRACT

In the concrete era of construction activities, there is scarcity of land especially in metro cities. Even though if there is availability of land it may in the sloping ground, hillocks or on land filled areas, in such areas there will be difficulty in the construction and design aspects. To maintain the slope of the strata, different degrees of such buildings step back towards the slanting slope and may likewise also have set back simultaneously. Hence in the present paper, an attempt has been made to study, G+12 storey building assumed to be in flat ground and also on sloping ground with 20 degree inclination. The model considered to be a soft storey with infill walls and two different shear wall arrangements. The building has been modelled in ETABS software with response spectrum method of analysis. The study reveals that model with shear wall improves the performance of the structure in terms of displacement, drift and time period apart from the fact that the structure being constructed in normal ground or sloping ground.

Keywords: shear wall, response spectrum method, displacement, drift, time period, base shear and GMT (Ground, Middle and Top) soft storey.

1 Introduction

In hillocks, valleys and undulated grounds there will be variation in the components of building, especially the reinforced concrete columns, beams and slabs which will vary with different heights, irregular mass distribution, mass and stiffness unequal distributions. These parameters alter the building responses. In many of the high rise structures to have functional requirement, generally the ground floor or first floor are kept open for vehicle parking, this stage will arise soft storey. This soft storey will make structure weak and less stiff. The rigidity of this floor is less than that of the normal floor. In multi storeyed framed structures, a linear dynamic analysis is carried out based on the theory of structural dynamics and the members are designed to have the required strength and stiffness. This method, popularly known as the model analysis or the response spectrum method has been in use particularly for irregular structures. The main objective of this work is to improve the structure resting on a sloping ground.

1.1 Literature Review

Vaidya, P. R et al (2015) carried out the model of structure on the sloping ground. They varied the position of shear wall to understand the exact position of the same. It was concluded that short columns are more critical in sloping ground. Sripriya Arjun et al (2016) studied the effect of low-rise structure with G+ 3 storeys using STAAD pro software. Based on their results they concluded that increased slope angle causes the decrease of displacement and base shear was more in longitudinal direction than in transverse direction. Pratiksha Thombre et al. (2016) analysed G+ 5 storied building located in zone 5 and resting on plain as well as slopping ground

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with response spectrum method using STAAD pro software. The results reveal that building with shorter slope will have less displacement than the one resting on higher slope. Paresh, G et al. (2016) worked on step back and step back structure of G+10 using SAP2000 software. In their work both response spectrum and time history analysis were executed. The dynamic nature of the structure is different from simple static anlaysis. From the study it is noticed that, both steps back and set back buildings are more favorable than set back building alone. The results such as Base shear, axial forces, and moments were studied and compared with the different analytical approach.

1.2 Objectives of the project

i. Analysis of infill frame with seismic loading on an slopy ground.
ii. Study the effect of soft storey and to increase the performance of shear wall on an sloping ground.
iii. To evaluate the parameters like displacement, base shear, drift and time period for normal and sloping ground at an angle of 20 degrees using response spectrum analysis.

1.3 Response spectrum method

This approach allows the multiple response modes of a building. Computer analysis can be used to determine these patterns of structure. For each mode, the response is obtained from the design spectrum, corresponding to the modal frequency and the modal mass, and then they are combined to estimate the total response of the structure.

2 Methodology

For the present study, multi storey RCC building G+12 was analysed by ETABS software (2017) considering soft storey, masonry infill, L and C type of shear wall. The details of the building are presented in Table 1.

Table 1 Parameters considered for modeling

1	**Properties of members**	
	Poisson's ratio Density Grade of concrete Yield strength of steel	0.2 25 kN /m^3 M40 Fe500
II	**Seismic Parameter**	
	Zone value (Z)	0.36
	Response reduction factor(R)	5 (S.M.R.F)
	Importance factor	1
	Damping ratio	0.05
	Soil Type	Medium
III	**Size of Members**	
	Height of building	39 m (G+ 12 storeys)
	Storey to storey height	3m
	Span length	5m
	Column sizes	1200mm x 1200mm, 750mm x 1000mm, 550mm x 750mm
	Beam size	230mm x 600mm
	Slab thickness	150mm
	Wall thickness	230mm
IV	**Load Intensity**	
	Live load on each floor	3 kN/m^2
	Floor finish	1.5 kN/m^2

The models with different combination are considered as suggested in the objectives and are presented in Figures 1 to 8

2.1 Models used in the present study

The details of the proposed study have been presented in the models below.

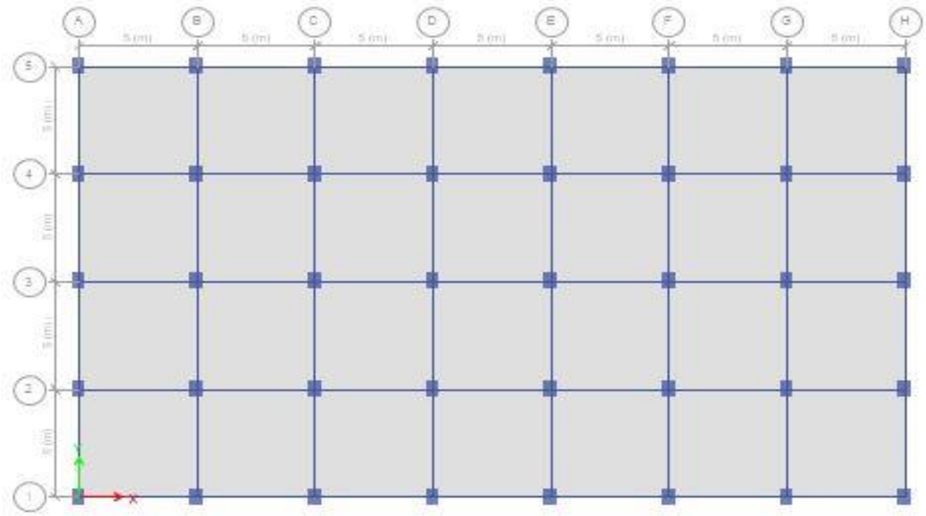

Figure 1. Typical Plan

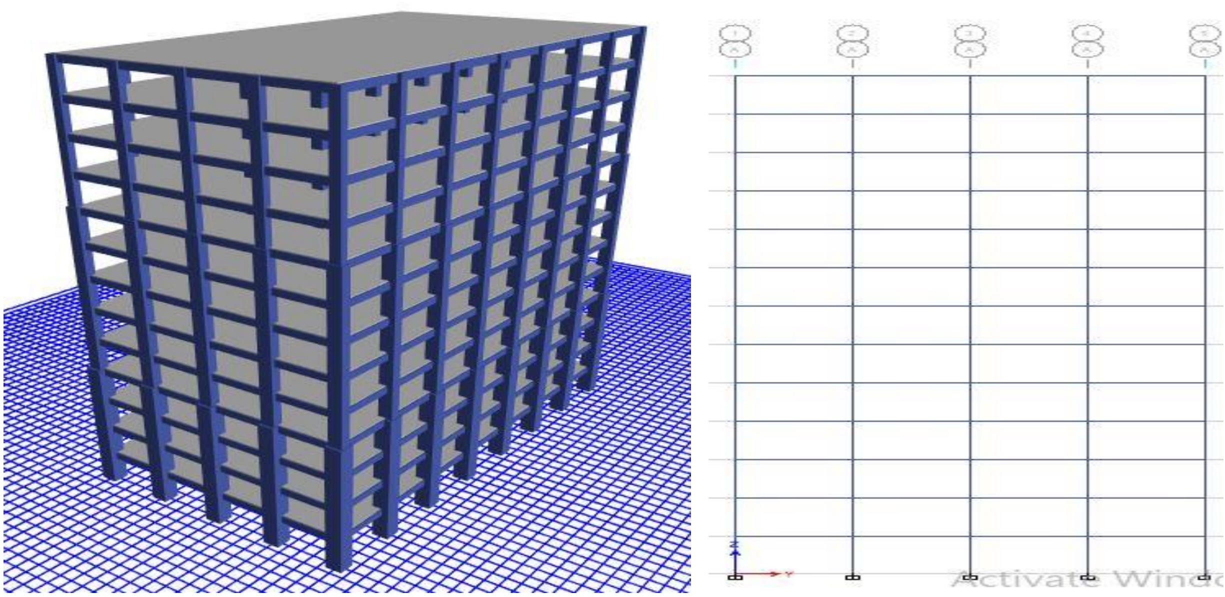

Figure 2. Elevation View

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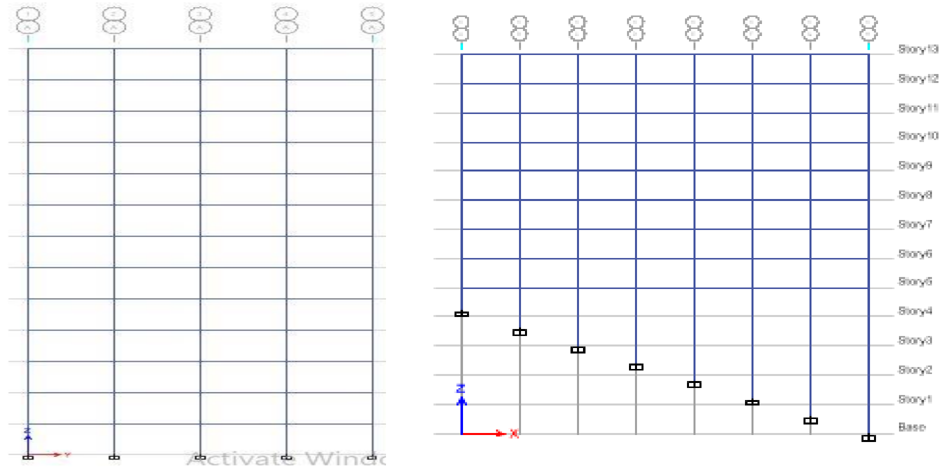

Figure 3. Elevation of 0^0 and 20^0

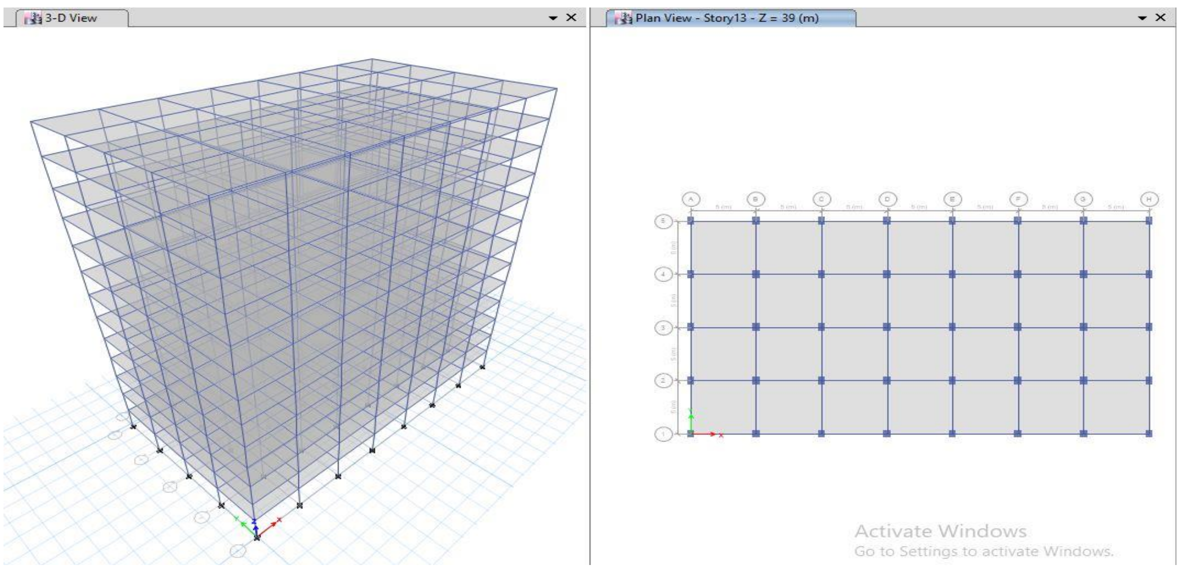

Figure 4. Bare frame (Model B1 and D1)

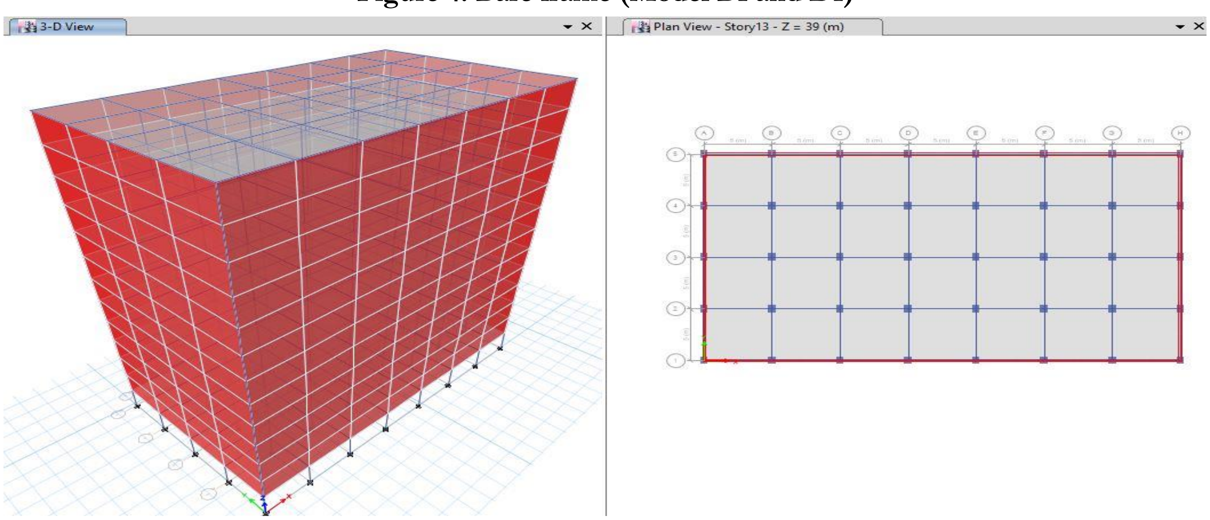

Figure 5. Masonry infill (Model B2 and D2)

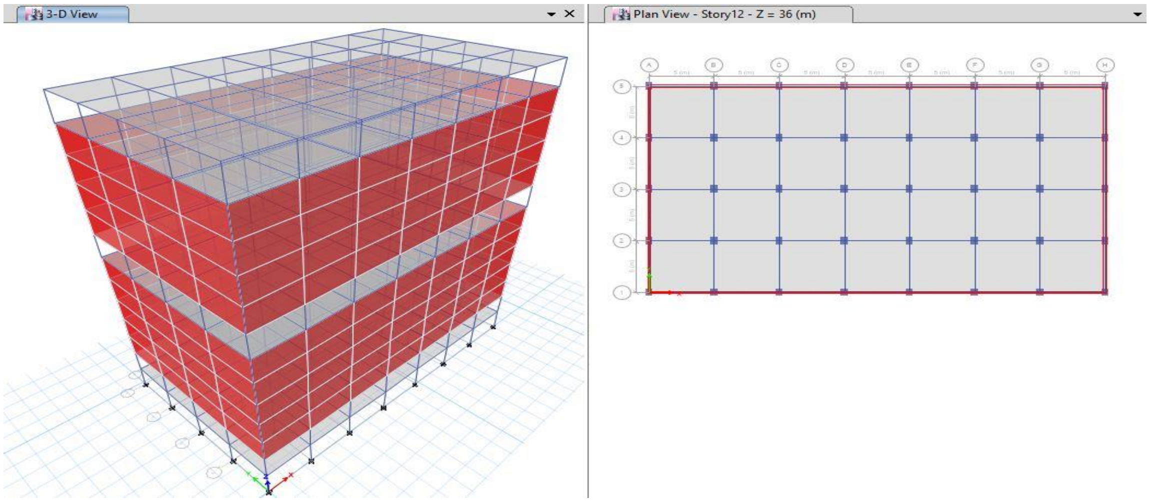

Figure 6. GMT with soft storey (Model B3 and D3)

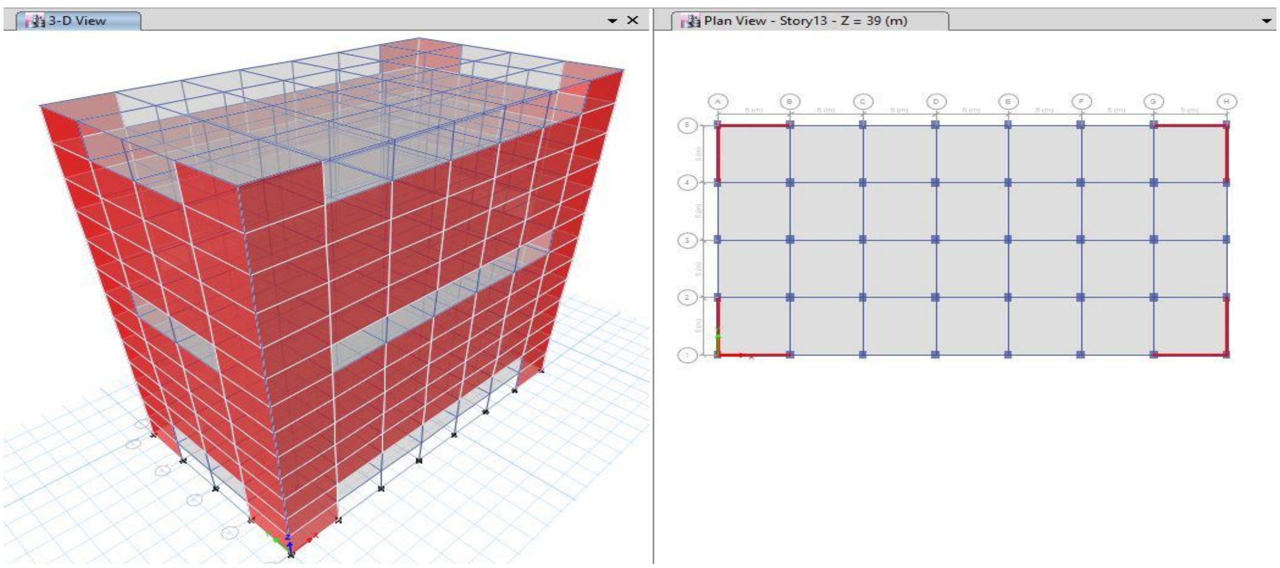

Figure 7. GMT with L type shear wall (Model B4 and D4)

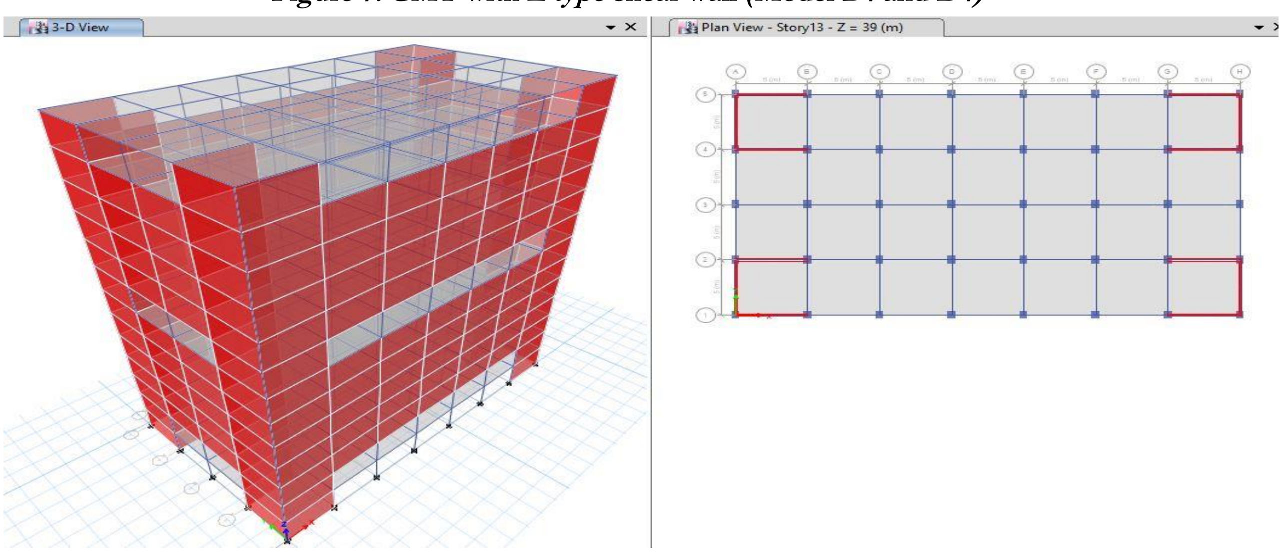

Figure 8. GMT with C type shear wall (Model B5 and D5)

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3 Results and Discussions

The results of buildings on flat ground and inclined ground are compared by considering Masonry Brick Infill, GMT soft storey, GMT with L type shear wall and GMT with C type Shear wall. The lateral responses like displacement, storey drift, time period and base shear are evaluated and compared.

Models B1, B2, B3, B4 and B5 for 0-degree plane ground.

Models D1, D2, D3, D4 and D5 for 20-degree sloping ground.

3.1 Displacement (zero degree slope)

The displacement of the models which were analysed are presented in Table 2 and Figure 9, from those it can be observed that, the model B1, the one which is bare frame is having maximum displacement compared to other models. The reduction of displacement is found maximum in model B5 (GMT with C type shear wall). The displacement is increase nominally for B3 model compared to B2.

TABLE 2 Displacement for normal ground (zero degree slope)

Storey	Model B1	Model B2	Model B3	Model B4	Model B5
13	29	9	11	6	5
12	28	9	10	6	5
11	27	9	10	5	4
10	25	8	9	5	4
9	22	8	9	4	4
8	20	7	8	4	3
7	17	6	7	3	2
6	14	5	6	3	2
5	11	4	5	2	2
4	7	3	3	1	1
3	5	2	2	1	1
2	2	1	1	1	0
1	1	0	0	0	0
0	0	0	0	0	0

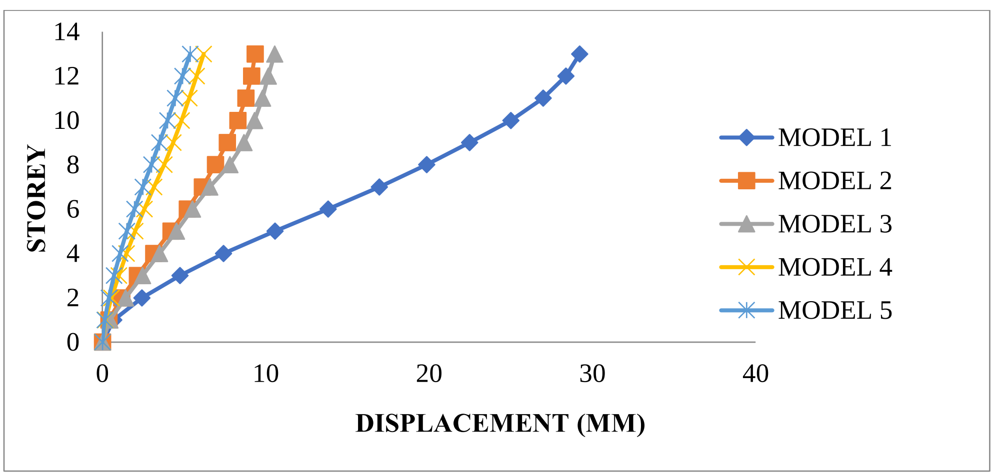

Figure 9. Storey with displacement (Normal ground)

3.2 Displacement (20 degree slope)

Table 3 and Figure 10 shows that model D1 is having maximum displacement in comparison with other models. The same observation will also hold well here, as the model D5 (GMT with C type shear wall) has lesser displacement. It can be generalized that bare frame model is more critical than the one which has shear wall.

TABLE 3 Displacement for sloping ground (20 degree slope)

Storey	Model D1	Model D2	Model D3	Model D4	Model D5
13	18	6	7	4	3
12	17	5	6	4	3
11	16	5	6	3	3
10	14	5	5	3	2
9	11	4	5	2	2
8	9	3	4	2	2
7	6	3	3	2	1
6	4	2	2	1	1
5	2	1	1	1	1
4	0	0	0	0	0
3	0	0	0	0	0
2	0	0	0	0	0
1	0	0	0	0	0
0	0	0	0	0	0

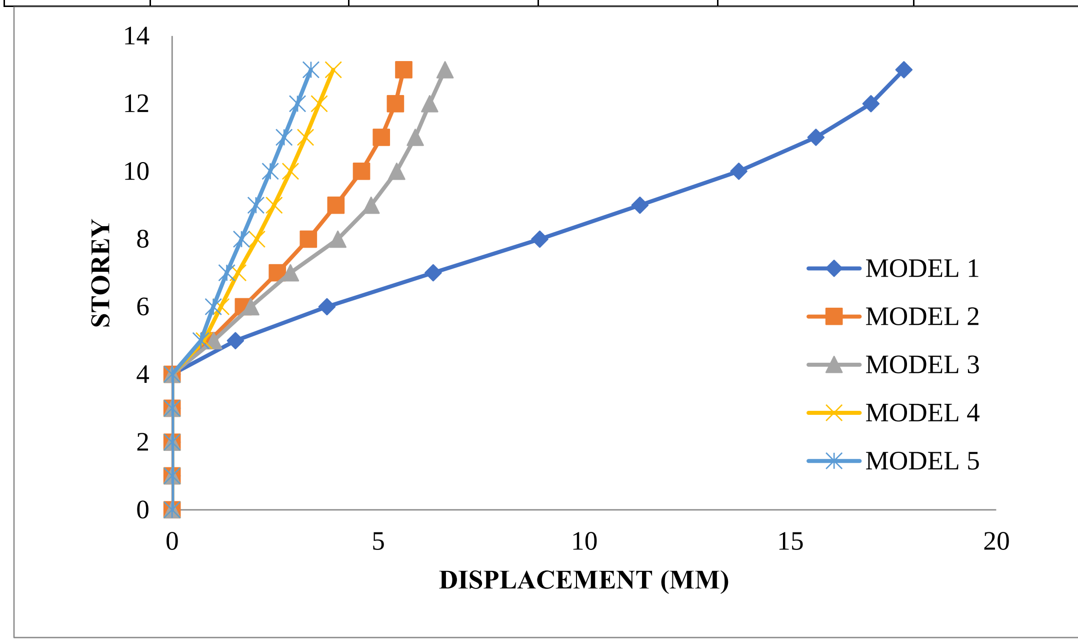

Figure 10. Storey with displacement (20 degree slope)

3.3 Lateral storey drift

As we know that storey drift is important for calculation in any earthquake study, based on our results shown in Table 4, 5 and figures 11,12 it is very much clear that there is no effect of drift in the various modelled analysed either in normal or sloping ground. It can be concluded that there is no effect of drift in general for the models chosen.

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TABLE 4 Drift for normal ground (zero degree slope)

Storey	Model B1	Model B2	Model B3	Model B4	Model B5
13	1	0	0	0	0
12	1	0	0	0	0
11	2	0	0	0	0
10	3	1	1	1	0
9	3	1	1	1	1
8	3	1	1	1	1
7	3	1	1	1	0
6	3	1	1	1	0
5	3	1	1	1	0
4	3	1	1	0	0
3	2	1	1	0	0
2	2	1	1	0	0
1	1	0	0	0	0
0	0	0	0	0	0

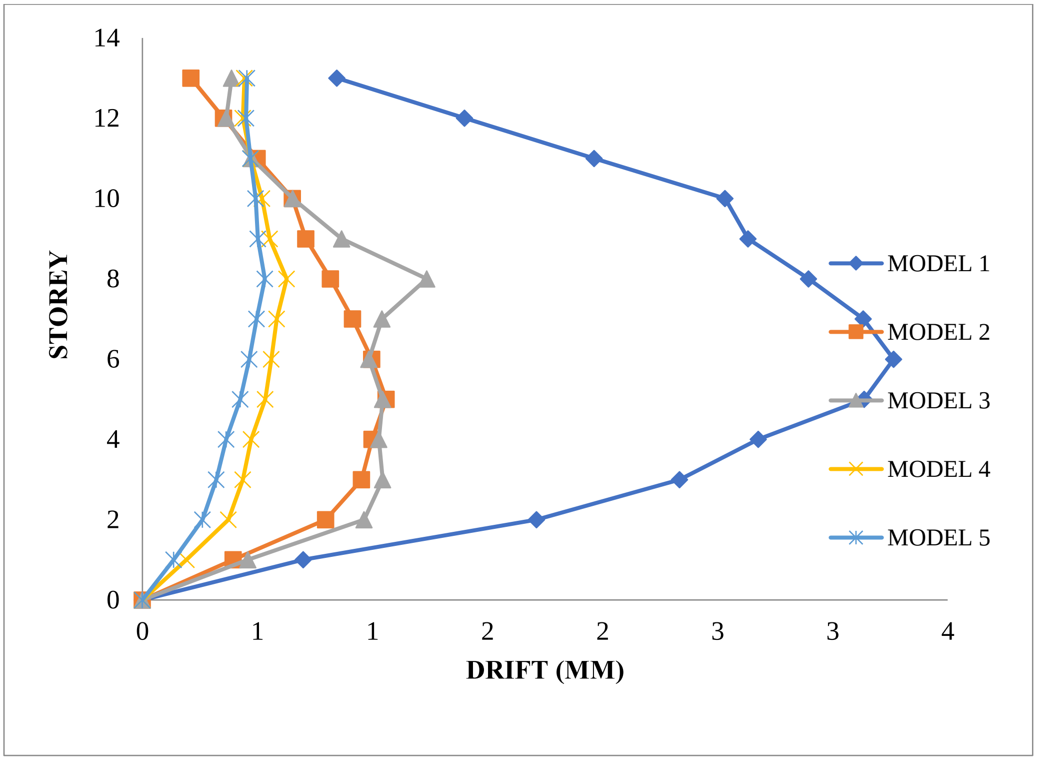

Figure 11. Storey with drift (Normal ground)

TABLE 5 Drift for sloping ground (20 degree slope)

Storey	Model D1	Model D2	Model D3	Model D4	Model D5
13	1	0	0	0	0
12	1	0	0	0	0
11	2	0	0	0	0
10	2	1	1	0	0
9	2	1	1	0	0
8	3	1	1	0	0
7	3	1	1	0	0
6	2	1	1	0	0
5	2	1	1	1	1
4	0	0	0	0	0
3	0	0	0	0	0
2	0	0	0	0	0
1	0	0	0	0	0
0	0	0	0	0	0

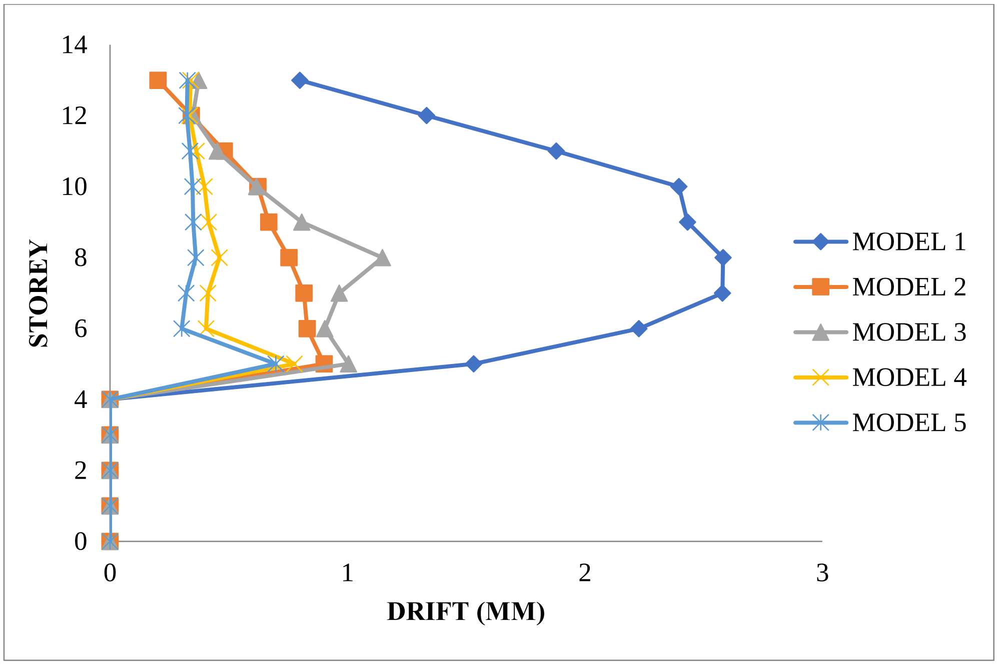

Figure 12. Storey with drift (sloping ground)

3.4 Base shear

Table 6 and Figures 14 and 15, it can be observed that the base shear is higher for model B5 and model B2, which makes us clear that the model having C type shear wall has highest base shear, this makes us clear that base shear depends on seismic mass of the structure.

Table 6 Base Shear results

Models	*Normal ground*	*Models*	*Sloping ground*
B1	*5185*	*D1*	*3726*
B2	*5253*	*D2*	*3825*
B3	*5062*	*D3*	*3628*
B4	*5168*	*D4*	*3714*
B5	*5325*	*D5*	*3831*

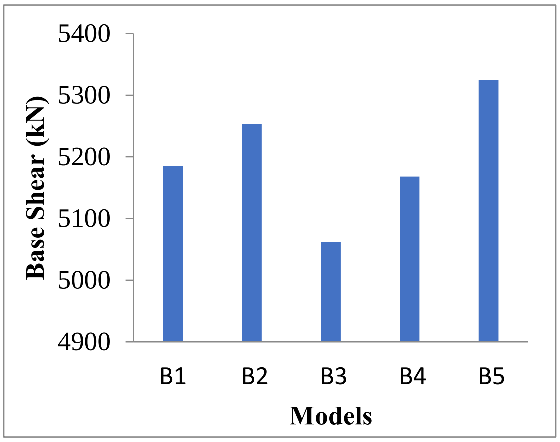

Figure 13. Base shear with models (N. G)

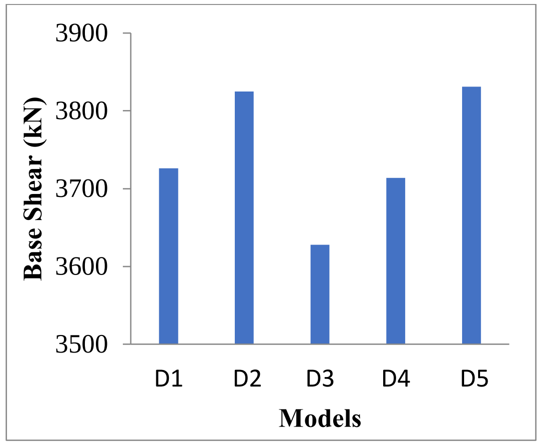

Figure 14. Base shear with models (S. G)

3.5 Time period

The time period of a model B1 and D1 as indicated in Table 7, 8 and Figures 15 and 16 has higher values and found to be flexible among other models. From these values it can be generalized that shear wall models are rigid with less time period.

TABLE 7 Time period for normal ground (zero degree slope)

Mode Number	Model B1	Model B2	Model B3	Model B4	Model B5
1	1.28	0.87	0.89	0.59	0.57
2	1.25	0.72	0.76	0.54	0.49
3	1.17	0.59	0.62	0.35	0.35
4	0.42	0.29	0.30	0.18	0.17
5	0.41	0.25	0.26	0.17	0.14
6	0.39	0.20	0.22	0.11	0.11
7	0.24	0.16	0.17	0.09	0.09
8	0.22	0.14	0.16	0.09	0.07
9	0.21	0.12	0.13	0.06	0.06
10	0.15	0.11	0.11	0.06	0.06
11	0.14	0.10	0.11	0.06	0.05
12	0.13	0.08	0.09	0.04	0.04

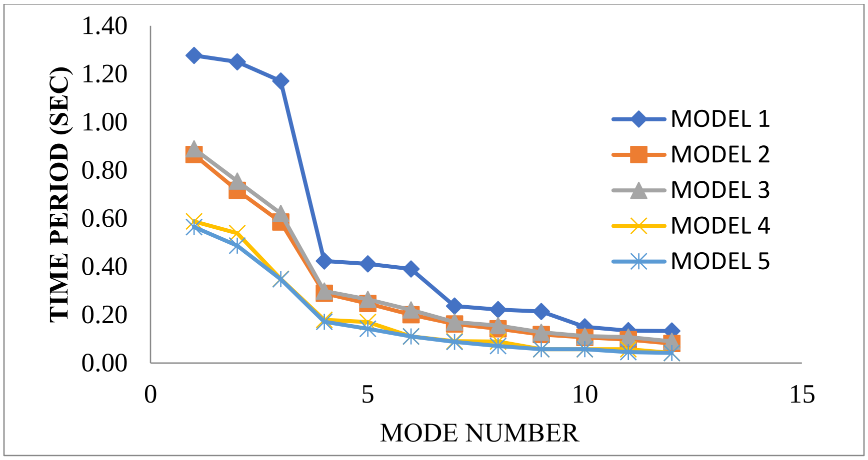

Figure 15. Time Period for normal ground

TABLE 8 Time period for sloping ground (20 degree slope)

Model Number	Model D1	Model D2	Model D3	Model D4	Model D5
1	1.04	0.72	0.78	0.57	0.57
2	0.96	0.55	0.60	0.45	0.41
3	0.87	0.45	0.50	0.31	0.30
4	0.33	0.23	0.26	0.16	0.16
5	0.32	0.19	0.24	0.15	0.13
6	0.28	0.18	0.19	0.11	0.10
7	0.18	0.16	0.17	0.10	0.10
8	0.17	0.12	0.16	0.08	0.08
9	0.14	0.11	0.14	0.08	0.07
10	0.11	0.10	0.13	0.08	0.06
11	0.11	0.09	0.11	0.07	0.06
12	0.09	0.09	0.09	0.07	0.06

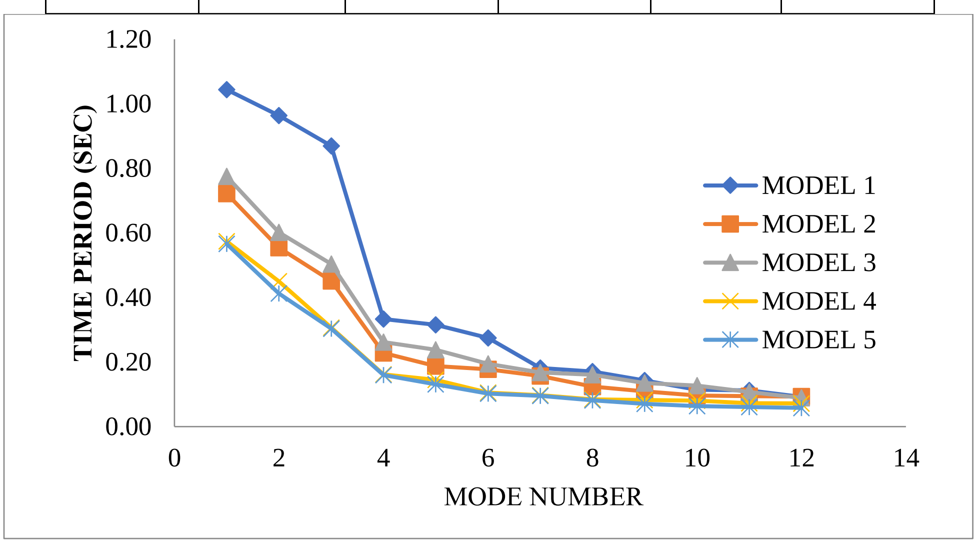

Figure 16. Time Period for sloping ground

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4 Conclusions

The following conclusions can be drawn with the present investigation

- The basic parameters in the analysis like displacement, drift, base shear and time period were maximum in bare frame model (B1 and D1)
- The displacement in the models can be reduced by providing masonry and shear wall. There was drastic change in displacement in the order of 69%, 63%, 80% and 83% for models 2, 3, 4 and 5 in comparison with model 1.
- The drift values obtained for the models were within the limits. i.e., h/250 = 3000/250 = 12, hence all models in 20-degree sloping ground are safe and well within the permissible limits.
- The base shear was higher for model 5 (shear wall) due to the seismic weight of the structure.
- Bare frame (model 1) is more flexible since it has the highest time period. The time period also varies from 32%, 30%, 54% and 55% for model 2, 3, 4 and 5 when compared with model 1. The Response spectrum analysis displacement values are lesser than static analysis values. The reduction in displacement value is around 20%.
- The drift values of all the models subjected to dynamic analysis are within allowable limit and all models are safe.
- From the modal analysis, it is found that, the model 1 is very much flexible and having highest time period and time period will decreases by 32%, 30%, 54% and 55% for model 2, 3, 4 and 5 in comparison with model 1.
- The Model 4 and model 5 are equally stiffer and hence the time period values are lesser comparatively.
- Shear wall improves the performance of the structure in terms of displacement, drift and time period.

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